NASA RESEARCH GRANT NGL 05-007-003

SEMIANNUAL REPORT FOR THE PERIOD

MARCH 1, 1969 through AUGUST 31, 1969

THE UNIVERSITY OF CALIFORNIA, LOS ANGELES

INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS

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Submitted by:

W. F. Libby, Institute of Geophysics and Planetary Physics

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LOS ANGELES

The NASA supported Space Program at U.C.L.A. is now in its eighth year. This year the NASA sustaining Grant was funded at $300,000 for the Physical Sciences and $150,000 for the Bio-science program. During this period 109 faculty have participated, as principal investigators, in this program. In the last three years 16 students have earned Ph.D's and 33 have earned Master's Degrees through research supported under this grant.

Many projects which began as seeding projects under this grant have grown into individual projects supported by the Army, Air Force, AEC, NSF, and other NASA offices, state governments, Departments of the Federal Government and private industry.

Our NASA built Space Science Center houses the Brain Research Institute, and the Atmospheric Research Laboratory, along with nine other research facilities.

U.C.L.A.'s Space Program has played a leading role in the development of NASA programs and is now looking toward the environmental sciences and the use of space technology as a means of solving some of man's environmental problems.

Members of the Space Committee along with leaders in industry and experts in the area of environmental sciences are actively pursuing the creation of a new program which would lead to a doctoral degree in Environmental Science and Engineering.

The emphasis will be placed in producing graduates who will have a broadly based background which will allow them to serve as experts on environmental problems, and consultants to government and industry in determining the effects of products and decisions on the public sector.

We are confident that the direction toward environmental technology will be a major contribution to man, NASA and to the University.

CRYSTAL GROWING LABORATORY

H. Bommel, G. C. Kennedy, J. Haygarth and W. F. Libby 448694

We are actively trying to devise a laboratory press which will exert a million atmospheres pressure on a volume of about one cubic centimeter. We believe that it will require diamonds to replace the tungsten carbide used at present in the pistons and cylinders, and at the moment our main objective is to find a material to bind the diamonds.

Some years ago it was discovered in our laboratories (A.J. Darnell, 1964, Ph.D. thesis) that there is a particularly simple relation between the pressure at which diamond lattice solids collapse to the denser metallic tin lattice and the electron energy gap for the diamond lattice crystals, ('Electron energy gap' is the minimum energy needed to promote valence electrons to the lowest conduction levels.) Thus if the electron energy gap were 2 volts, then the pressure would be equal to 1 volt divided by the volume change per mole on collapse of the lattice to the metallic form, proper attention being given to units. For a 2 volt energy gap in a solid suffering a 1 cc/mole decrease in volume on compression from the diamond to the metallic tin lattice, a pressure of 100,000 atm. would be required. Table I is a compilation of these data. From this analysis it is clear that diamond with an energy gap of 5.6 electron volts would require some 3,000,000 atm. to collapse to the tin form. In Table II are listed the electron energy gaps

of the various diamond lattice solids. From these data only cubic BN, boron nitride, might be expected to require a higher pressure.

Therefore it is our intent to learn to bond diamond or cubic boron nitride. If we succeed in making a matrix of diamond with some binder (analogous to cobalt in tungsten carbide) it would be used to build a press the inner surfaces of which are bonded diamond. This surface would be encased by bonded tungsten carbide and finally by the usual high strength steels. In this way we hope to move forward into the general pressure range of a million atmospheres. This would further open to experimental investigation the whole area of the properties of matter under extreme pressures, and shed more light on the nature of planetary interiors which attain pressures of millions of atmospheres. Quite possibly this apparatus would allow us to work on the atomically degenerate dense metallic state of matter long supposed to exist in the interior of Jupiter.

TABLE I

Comparison of the $P\Delta V$ Work for the Semiconducting Metallic Transition with E_g of the Semiconductor [Jamieson (29)]

Substance	Transition Pressure (kilobars)	ΔV (cm^{-3}/mole)	$P\Delta V$/atom (ev)	$\Delta E_g/2$ (ev)
Sn	- 0.7	4.3	0.003	0.03
InSb	+ 22	7.59	0.09	0.09
Ge	120	2.85	0.32	0.32
Si	200	2.73	0.56	0.54
GaAs	240	5.52	0.69	0.69
C		0.72		2.80
GaSb	90	5.19	0.22	0.35
AlSb	125	4.97	0.32	0.75
InAs	102	5.82	0.31	0.18
InP	133	5.45	0.38	0.60

TABLE II

Energy Gap of Semiconductors with the Diamond or Zinc-Blende Structure (e.v.)

IV	III-V	II-VI	I-VII
Sn(gray) 0.08	InSb 0.18	CdTe 1.45	AgI 2.8
Ge 0.70	GaAs 1.4	ZnSe 2.6	CuBr 2.9
Si 1.10	AlP 2.36		
C (diamond) 6	BN 10		

PHYSICAL VAPOR DEPOSITIONS OF ALLOYS

Dr. R. F. Bunshah 448617

Alloys are prepared by physical vapor deposition techniques, i.e., by evaporation of the alloys constituents from single or multiple sources followed by condensation on a suitable substrate. In this manner, simple shapes like sheet, tubes, etc., can be produced directly as contrasted to the more common route of casting followed by fabrication. Previous work has shown that high purity material with very fine grain sizes can be produced by physical vapor deposition processes.

The work is important scientifically because it is a new way to prepare and study ultra fine grain size materials. Technologically, it should lead to alloys with very high strengths, roughness and possible with superplastic behavior for use at ambient and elevated temperatures.

Start of the work awaits delivery of other apparatus, and hence no graduate students are working on it at this time.

MAGNETICALLY SHIELDED TEST FACILITY

Paul J. Coleman, Jr. and Robert C. Snare 448623

1. During the reporting period the facility continued to house an OGO-5 type magnetometer. This instrument was a spare flight unit for a spacecraft which was launched March 4, 1968.

The instrument and the shielded room are used to simulate spacecraft anomalies.

During this same time, we have used the facility in the development of new circuitry and to test magnetometer bread-boards. We also used the room to perform preliminary evaluation of sensors for the ATS-F magnetometer instrument.

2. The magnetically shielded room provides a stable area relatively free of magnetic fields for the investigation of magnetic phenomena.

3. The facility provides a stable, low-field area in which to evaluate scientific instruments and spacecraft hardware.

4. The graduate students involved with the facility are Larry Sharp and J. Dale Barry.

DISSOCIATION OF H_2 BY ELECTRON IMPACT: PRODUCTION OF H^+ AND METASTABLE H ^{2}ATOMS

Dr. A.U. Hazi, Dr. M. F. Fels 448614

This project involves a theoretical investigation of the scattering of electrons from molecular hydrogen, in which, by dissociation of the molecule, atomic hydrogen in the 2S state is formed. Two relevant experiments have been reported -- they disagree with respect to the energy distribution of the products. In addition to carrying out a calculation of the cross section

for this process, we hope eventually to be able to explain the discrepancy between the two experiments.

In order to calculate the cross section for $e + H \rightarrow e + H(2S)$, one needs first to determine which dissociating states of H_2 participate in the reaction. The potential curves for these states, if not already known, must be calculated so that the scattering wave functions for dissociating H_2 (in the Born - Oppenheimer approximation) may be found. Some of the participating states are doubly excited autoionizing states; we are presently calculating the potential curves of these using the method stabilization.

The method of stabilization is a powerful tool for finding the energies of autoionizing states. In the course of this project we will continue to investigate the ability of the method to predict properties other than the energy; e.g., the lifetime for autoionization and other modes of decay.

The project described in Part I of this report is part of an extensive program undertaken to study reactive processes involving isolated molecules. From the theoretical point of view, a complete understanding of the hydrogen molecule is of special importance because it is the simplest neutral molecule known. For this reason: (i) a better understanding of the electronic structure and the reactivity of H_2 is prerequisite for the study of more complicated molecules (ii) with presently available for H_2 which is very helpful in developing a valid

theoretical model for reactive processes involving molecules.

The graduate student involved in this project was Mr. Shur-Jin Tsay.

SUPERTHERMAL BEAM STUDIES

R. K. B. Helbing 448699

Superthermal beam studies in the energy range of 1.5 eV to about 30 eV (and higher if needed) are planned. The proposed research includes the production of superthermal beams via charge-exchange and the development of a general-use, low-noise detector for superthermal beams. A molecular beam apparatus will be constructed for molecule-molecule collision measurements (total and differential cross sections). Elastic scattering as well as inelastic and reactive scattering will be studied. In particular the study of intermolecular potentials and closely related collision processes is emphasized (e.g. the physical states [orbiting, complex formation, etc.] prior to and including chemical reactions, charge transfer, ion production, dissociation, excitation, etc.). Since the binding energies in molecules are typically in the energy range mentioned above, one expects detailed information on chemical reactions in various stages of proceeding.

Special equipment to be built includes various types of thermal and superthermal beam sources, special velocity selectors, and detector equipment. Low noise amplifiers, lock-in detection devices, multipliers, and other specialized electronic equipment will be either bought or built.

METHODS OF ORBIT DETERMINATION AND INTEGRATION: CURRENT WORK ON ICARUS AND JUPITER'S SATELLITES IX AND XII

Samuel Herrick 448630

We have maintained our continuous study of Icarus and Jupiter satellites IX and XII during the past six months. The motions of these minor planets are used as an orbit laboratory for specific research projects, and also for the instruction of graduate students, in the following manner: We secure by personal contact and correspondence accurate, difficult-to-obtain data from appropriate observatories. These are sent to us immediately for careful analysis, integration, and constant correction so that, on the basis of refined and accurate orbit prediction the planets in question can be maintained under observation. Fifteen years of constant work by the Principal Investigator have been necessary to make full use of Icarus' last close approach to the earth in June 1968; scientific results of this work are only now beginning to be ready for publication.

This work of refining methods and formulae for accurate

orbit determination is of prime importance in calculating trajectories of spacecraft, especially where rendezvous of two craft is required. It is probably that only a university research environment could provide the great lengths of time necessary to compile and painstakingly refine this orbital data.

Four of the several graduate students involved with this project were financially aided by this sub-grant in this report period. George C. Tiffany Jr. will finish his work for the Ph.D. in 1970.

CHEMICAL LASER STUDIES IN EXPLOSION SYSTEMS

J. V. Kasper 448669

Two projects are being supported in part by this grant. One of these is the study of the production and subsequent relaxation of vibrationally excited hydrogen. Discharges in hydrogen have long been a subject of interest, but traditional measurements of the concentration of atomic hydrogen cannot differentiate between energy of atomic recombination and vibrational energy. In some preliminary experiments we have directly observed that approximately 2% of the hydrogen is vibrationally excited. The apparatus used, which measures concentrations of the various vibrational states of hydrogen and concentration of hydrogen atoms using vacuum ultra-violet absorption spectroscopy, is being

modified to permit more accurate measurements. We then expect to clarify the effects of various discharge conditions on the vibrational excitation of hydrogen.

Equally important is the realization of hydrogen both in the gas phase and at various surfaces. Although there are some very good theoretical studies of de-excitation of excited hydrogen by hydrogen atoms, there is a complete lack of experimental data concerning this. We hope to provide some much needed data.

The results of this work are technologically important because of the current importance of the laser. The N_2-CO_2-He laser is undoubtedly one of the most powerful and important lasers developed. Discharge excitation of the nitrogen is the crucial first step in its operation. It is highly possible that other lasers based on the initial excitation of hydrogen may result from our studies. Data on energy transfer in H_2 is also of extreme importance to our knowledge of the behavior of rocket propellents which contain hydrogen.

Mr. R.F. Hechner III, a graduate student, is involved in this project.

The second project represents one aspect of our study of reactions suitable for pumping chemical lasers. We are constructing an apparatus which will use the output of a chemical laser to probe in detail the instantaneous behavior of related chemical systems. Appropriate computer programs will be used

both to indicate which experiments should be performed and to aid in the interpretation of experimental results.

The studies should help to determine exactly when the energy of a chemical reaction initially appears and what happens to this energy later. Such information should permit the improvement of existing chemical lasers and aid in the development of new lasers, as well as promoting a better understanding of several combustion processes.

Mr. James Campbell, a graduate student, and Mr. Dan Tenen, an undergraduate, are assisting the research.

AIR POLLUTION RESEARCH

R. Kopa 448613

The yield of nitric oxide from a constant volume combustion of three different fuels and air was investigated. The combustion experiments were carried out in a reaction vessel made either of pyrex, pyrex coated with carbon, stainless steel, or black iron. The concentration of nitric oxide in products was independently determined by use of Saltzman reagent and the electric conductivity method, a procedure developed on this project. The pressure-time history of the combustion process, which is indicative of the flame speed, total energy-release, and of the peak (mixed mean)

combustion temperature, was recorded for each run by a pressure transducer and a high-speed Sanborn strip-chart recorder. A conventional spark plug was used to ignite the mixtures. All fuels were combusted at stoichiometric ratio and at identical initial conditions (p, T). The experimental data accumulated to date indicate the following trends:

1) The highest yield of nitric oxide was obtained from the combustion of hydrogen (about 2000ppm) and the lowest from the combustion of methane (about 500ppm). Carbon monoxide yields about 1200ppm. The same peak pressure (about 6 atm) resulted during explosion of each of these gases.
2) The highest yields for each fuel was obtained in pyrex (and carbon-coated pyrex) reaction vessels. The lowest yields occurred in black iron vessels. The difference depended on the type of fuel and was largest for hydrogen (about 30%) and smallest for carbon monoxide (insignificant).
3) The most consistent data were obtained with methane and the least consistent with hydrogen. The variation in the latter case was by two orders of magnitude. (Since the pressure-time histories and the energy release as well as the peak combustion temperature should be the same in the case of the maximum (2000ppm) as well as the minimum (~20ppm) yield of nitric oxide).

This extreme range of yields of nitric oxide from hydrogen-air combustion is of interest and deserves further investigation.

These experiments are aimed at reducing the emission of nitric oxide by internal combustion engines, a prime source of smog producing air pollutants.

CHEMICAL ANALYSIS OF THE SOLAR WIND (LAUNDRY BAG)

D. Lal, W. F. Libby, and D. S. Sethi 448635

The project to collect the heavier and less abundant elements of the Solar Wind for chemical analysis in a manner analogous to that employed on Apollo 11 for hydrogen and helium has been substantially accelerated by the apparent success of Apollo 11.

Our finding that aluminum is the best material for the capture of the Wind (D. Lal, W. F. Libby, G. Wetherill, J. Leventhal and G. D. Alton, Collecting a sample of the solar wind: an experimental study of its capture in metal films, J. of Appl. Phys., 40, 3257-(1969) has led us to concentrate on preparing ultrapure aluminum. Our approach has been to carefully purify aluminum tri-isobutyl, a metallo-organic compound. Then, thermal decomposition of the purified aluminum alkyl causes metallic aluminum to be deposited. The only impurities likely are those

elements contained in the isobutyl compound, carbon and hydrogen; but these are not expected to be any problem since we plan to analyze by neutron activation, a technique insensitive to both. Thus it seems that we may have a method for producing a metallic aluminum film sufficiently pure for the neutron activatable elements to allow us to detect and analyze the Solar Wind for these elements.

Such a film would be deployed either on the surface of the moon, on which the Wind presumably impinges freely, or in an orbiting satellite. If it were possible to prepare aluminum containing no more than 10^{-13} grams of sodium per gram of aluminum, then a five foot square sheet of plastic coated with a 2 mil thick layer of aluminum would collect adequate wind in one day. This calculation assumes that the composition of the Solar Wind is the same as that of the sun as given in standard tables (2×10^{-6} atoms of Na per atom of H).

The film would then be rolled up, placed in a container, brought back to earth, and placed without opening into an atomic reactor. In this way there is no chance of the foils being contaminated by handling or the earth's atmosphere. Thought is now being given to aluminizing the plastic surfaces in space.

With a sample of the Wind as described above some 16 disintegrations per minute of radioactive Na^{24} could be produced by the use of a high flux reactor (10^{13} neutrons/cm^2/sec) in a radiation lasting a few days. (The MTR reactor at ARCO,

Idaho, could give several times this flux). Following this it would be necessary to dissolve the materials, chemically separate them from other radioactivities, and then to measure them in a sensitive low level counter.

We have had some conversation with one or two aerospace companies about the mechanics of maintaining a sheet of aluminum in orbit perpendicular to the direction of the Solar Wind and recanning it without contamination. Although this will involve some difficulty, we foresee no unsurmountable obstacles.

The main problem at this point is to obtain ultrapure aluminum for neutron activatable elements to which sodium oxide adheres as a leading member. Dr. Sethi's work, and the attempt, if successful, will be followed by a proposal to NASA headquarters.

RADIO REFLECTIONS BY FREE RADICALS

W. F. Libby, J.D. Barry, P.J. Coleman, and L. M. Libby 448692

In this study, we are attempting to show that a satellite borne swept frequency top side ionosounder, such as that on the Alouette II satellite, may be used to obtain information concerning many of the constituents of the Earth's upper ionosphere. The secondary signals often detected in the ionosounder ionogram data at frequencies below the electron gyrofrequency are stimulated by the sounder-transmitted pulse, and we have determined that the wave-particle interaction region is within about 100 meters

from the satellite.

We have suggested that the secondary signals result for stimulated transitions within the electronic hyperfine Zeeman structure of free radicals in the plasma near the satellite. The atomic species involved are identified by it to the theoretical values for the various metastable states. Two main peaks in our g value distributions are tentatively identified with $N(^2D_{3/2})$ and $N^+(^3P_2)$ states. The variations between day and night data tend to confirm these labels.

The main consideration now is the wave-particle interaction process in the plasma.

Graduate students: J. D. Barry - work was part of Ph. D. - Space Physics (1969).

GROWTH OF ORGANISMS UNDER HIGH CONCENTRATION OF CO_2

W. F. Libby and J. Seckbach 448696

The question of the possibility of life on Venus seems to turn on whether plants can live in a CO_2 atmosphere.

Growth in pure CO_2 at one atmosphere pressure in a hot acid medium has been demonstrated for the alga Cyanidium Caldarium obtained from the Yellowstone hot springs. In fact, at 40°C to 50°C in pure CO_2 and an acid medium (ph=2), the growth is more rapid than for aerated cells at room temperature and in a neutral medium (cf. Fig. 1).

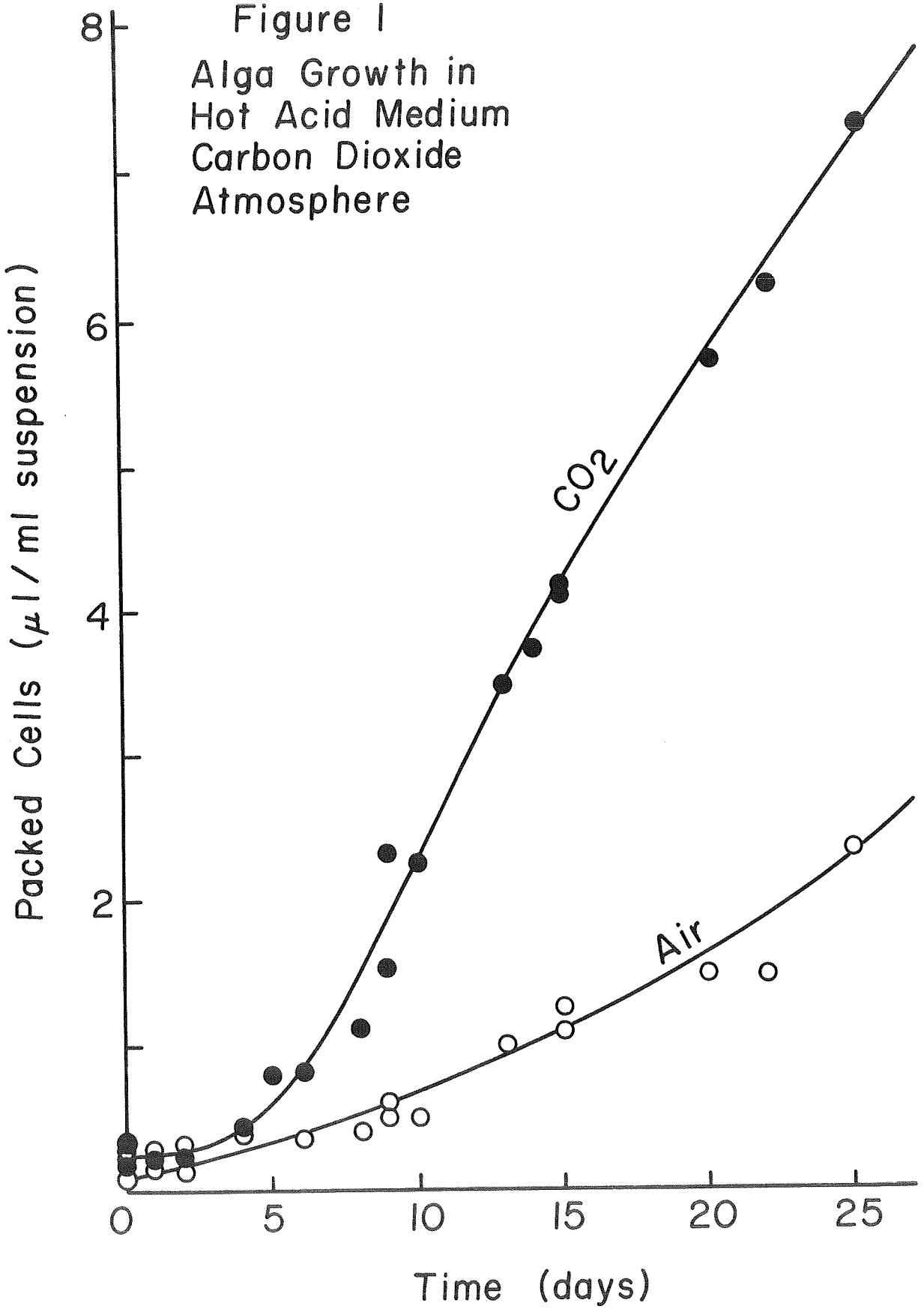
In a pure CO_2 environment accelerated growth occurred at 40° to 50°C while it was inhibited at lower temperatures. At these elevated temperatures the cells are larger and more numerous than the control cells, and have higher chlorophyll content per volume of suspension. Electron microscopic examination of these cells reveals conspicuously large chloroplasts which may occupy most of the cytoplasmic volume. Oxygen determination showed that this culture has a photosynthetic value (O_2 evolution + respiration) about triple that of the aerated cells. The amount of C and H detected for both lyophilized cells was similar while the ash showed much lower levels of the tested elements over the control.

These studies constitute the first report to our knowledge concerning cell growth in pure CO_2 environment, and have special interest because the Venus atmosphere is extremely rich in CO_2. Our experiments at higher pressures have just begun and no conclusive results are in hand. However subjection to 50 atmospheres did not kill the alga and they resumed their normal rapid growth at one atmosphere. For various technical reasons as yet unresolved the question of growth at the high pressure remains unanswered. We hope to have this answer in the next report.

Our system of growing algae under pure CO_2 may have many new biological applications which we hope to investigate.

Figure 1

Alga Growth in
Hot Acid Medium
Carbon Dioxide
Atmosphere



PLASMA STUDIES

W.F. Libby, L. Wood 448615

The work supported by this sub-grant deals with the physics and chemistry of high energy density processes, with emphasis on understanding the nature and properties of dense, high temperature plasmas. Plasmas being very strong electromagnetic force fields onto a small (e.g. few cubic inch) volume of gas which is to be studied; the high-current discharge forms in this volume at temperatures determined by mass flow and electromagnetic power flux onto the region. The plasmas are typical and ultraviolet light outputs are studied in detail, to determine the nature of the various electronic processes occurring in the ionized gas system.

Plasmas of the type being studied in these research areas are of the composition, density and temperatures of the solar photosphere, chromosphere and lower corona; on improved understanding and more detailed elucidation light-producing layers of the solar atmosphere, and therefore, of how the sun controls the terrestrial atmosphere.

The basic technological justification for plasma studies is doubtless the contributions such investigations make to the ultimate solution of the controlled thermonuclear fusion problem, which holds the promise of virtually free, inexhaustible, clean power production. Academician Peter Kapitya of the Soviet

Union has, for instance, very recently announced some results of hitherto secret work in which very dense, multi-million degree denterium plasmas were coated and sustained for hours by radio frequency techniques basically very similar to those employed in this research; his plans for future research, which should bring him very close to economic fusion power production, involve experimental approaches even more similar to those employed and being prepared for employment by us.

Mr. Richard Davis is the UCLA graduate student primarily involved at present in these studies.

LOW-LIGHT LEVEL IMAGING INSTRUMENTATION

R. Mackey 448578

We are investigating an image scanning technique for observing the spatial distribution of a radioactive substance (tritium) selectively absorbed in organic tissue.

The system consists of a beta particle energy-to-light transducer which is optically coupled to a low-noise high-gain image intensifier. The image thus produced is displayed on a television monitor or photographed with a high sensitivity film. As an intermediate step, a slow-scan vidicon image tube was operated under conditions which varied in temperature, target voltage, and period of integration in order to determine the

parameters of optimum performance.

The technique worked out in this feasibility study reduces the time required for autoradiographs from days to minutes. This work should be of interest to pharmacologists who need to determine the distribution of drugs and their break down products throughout body tissue.

One student, Gaetan Richard, was supported by this project; he obtained his Ph.D. in December 1968.

SPECIAL REFERENCE TO THE ADVERSE EFFECTS OF METEOROLGOICAL MANIPULATION: DEVISING LEGAL AND POLITICAL CONTROLS

V. More 448631

As the exploration and use of outer space becomes more frequent, it is essential to prevent harmful uses of it which could affect both the terrestrial and extra-terrestrial environment. The present project seeks to grapple with this immensely important and urgent problem.

The Project falls into the following scheme:

1) Introduction: Space technology and law.
2) Conceivable categories of harmful uses of outer space.
3) Appropriate space law covering different categories.
4) Meteorological manipulation and international legal complications.
5) Conclusions and suggestions.

During the period from March 1, 1969 to September 30, 1969, a bibliography was prepared which covered the different aspects of the above, categorizing the pertinent literature which has been surveyed in a preliminary manner and a rough draft that has been prepared to flesh out the skeleton structure. This draft is presently being perused by Dr. E. A. Englebert, Director, MPA Program, UCLA, who is supervising the project.

It is expected that in the next academic year, intensive research on the various aspects of the research project would be conducted. If time and resources are available, it would be highly desirable that the principal investigator makes some "field" trips to important international, intergovernment agencies, especially United Nations, nearing upon the project.

RAMAN SPECTROSCOPY OF CALCIUM CARBONATE AT VERY HIGH PRESSURES

F. Nicol 448618

This project is part of an extensive, experimental investigation of effects of very high pressures on the structures and physical properties of solids as indicated by their vibrational spectra. The objectives of the encompassing program (1) to obtain a better understanding to bonding forces in solids; (2) to establish the mechanisms of phase transitions in solids under high pressures, especially in materials of geochemical

interest; (3) to predict the occurrence of new phases of known materials and conditions of their synthesis; and (4) to obtain Raman vibrational spectra of phases of materials that cannot be conveniently studied under other laboratory conditions. Raman spectra might be used to detect these and similar materials in highly stressed environments, e.g., craters and ejecta of meteorite impacts.

This particular project concerns Raman vibrational spectra of four phases of the calcium carbonate system at high pressures. Two of these phases have never been observed except under high pressure conditions, and their structures are unknown. The immediate goals of this project are to obtain high resolution Raman spectra of these phases. We hope to be able to use these spectral data, together with other, limited available information about these phases and known properties of the familiar aragonite and calcite phases, to infer the structures of these two phases.

Already, we have succeeded in taking high resolution spectra for several different sample orientations, and the careful intensity studies of these high resolution spectra are in progress. These confirm that none of the lines that have been identified are artifacts. The polarization and orientation studies have just begun, and it is too early to determine whether they will provide useful structural information. Only

very preliminary temperature dependence studies have been made. It is too early to discuss results of this work except to indicate that we have shown that 40-Kbar, Raman spectra can be obtained for temperatures up to 200°C.

In addition to Miss Mei Y. Fong, who will use this study as part of her Master's Thesis, two other graduate students and a post-doctoral scholar, all supported by AEC funds, are involved in this program.

RADIO ASTRONOMY

Kurt W. Riegel 448688

We are continuing work in alactic radio astronomy. The principal data consist of 21-cm line profiles, observed at the Owens Valley Radio Observatory and the National Radio Astronomy Observatory. These data are yielding information on the structure of the interstellar medium, temperatures and densities, on a large and a small scale.

Maps of the interstellar medium in the direction of thermal radio sources have been produced. The properties of a most remarkable cold cloud in the direction of the galactic center have been determined.

Such information is of critical importance in developing

realistic theories of star formation and of the details of physical processes taking place in the interstellar medium.

Opportunity for involvement in research was provided to one of our graduate students, Steve Kilston, although no actual salary payments were made from this account.

ANALYTIC AND EXPERIMENTAL STUDY OF INELASTIC AXISYMMETRIC DEFORMATION AND STABILITY OF SPHERICAL SHELLS

S. B. Roberts 448682

In the fields of civil and aerospace engineering, shell structures have long played an important role. In particular, they are used in pressure vessels, reentry vehicles, and dome roof structures. It is well known that most real structures of this kind experience both elastic as well as inelastic deformations while performing their designed functions. In order to properly predict their behavior we must extend our knowledge of elastic response into the inelastic domain. To this end we are specifically studying the inelastic large deformation behavior of spherical shells subjected to pressure and concentrated loads at the apex.

Our computer program has been modified to include the effects of inelastic strains in the governing field equations using the total deformation theory of plasticity. The program was checked out and a number of illustrative problems were solved.

Newton's method is used to solve the system of non-linear algebraic equations which arise from the finite difference decomposition of the governing differential equations. Kantorovich's theorem, which presents sufficient conditions for the convergence of Newton's method was applied to one converged solution. It was found that even though a converged solution had been obtained, the sufficient conditions were not satisfied.

Energy considerations were applied to the question of the multi-valuedness of the apex load deflection curves. Results showed that the curves are either single-valued, monotonically increasing or triple-valued depending upon the geometric parameter. These results correspond with experimental observations.

Work is continuing on obtaining stress-strain relationships for the materials used in tests that are reported in the literature and on obtaining test specimens for our experiments.

Mr. Stephen Wang, as Ph.D. candidate, has been receiving support under this grant. It is planned that this work will constitute his dissertation.

BIOLOGICAL RELATIONSHIPS AND EVOLUTIONARY DEVELOPMENT OF PRECAMBRIAN LIFE

J. William Schopf 448616

Studies in this laboratory are primarily concerned with

the biological relationships and evolutionary development of Precambrian life (i.e., organisms existing between 3.2 and 0.6 billion years ago). Related studies, currently underway or to be initiated in the near future, involve the investigation of algal microfossils from the Ordovician of Poland (ca. 475 million years old), primitive vascular plant fossils from the Devonian of Scotland (ca. 400 million years old), and lunar samples returned by Apollo XI.

1) Lunar Sample Studies.--- Five grams of lunar dust, and two one-gram rock fragments are being investigated for evidence of living, dead or fossil microorganisms. These studies involve optical microscopy and transmission and scanning electron microscopy, of powdered, embedded, macerated and thin-sectioned material.

2) Extractable Organic Matter in Precambrian Sediments. --- A recently completed study (with I.R. Kaplan and J.W. Smith) shows that the concentrations of n-alkanes, isoprenoids and fatty acids in ancient sediments are several orders of magnitude less than those reported previously, and that major problems are encountered in demonstrating the syngenetic nature of these compounds; whether such analyses can yield definitive evidence of early biochemical processes is therefore uncertain.

3) Carbon Isotopic Studies. --- In an effort to detect possible variations in the carbon cycle over geologic time, and

as a possible indicator of the time of origin of biological photosynthesis, Mrs. Dorothy Oehler (graduate student) is investigating the carbon isotopic composition (C^{13}/C^{12}) of cherts, stromatolites, carbonates and organic matter of Precambrian and Phanerozoic age.

4) Paleobiology of the Belt Supergroup. --- Mr. Robert Horodyski (graduate student) is completing his first field season, collecting and studying stromatolites, sedimentary structures and black chert facies of the Late Precambrian Belt Supergroup of Montana. Laboratory analyses of this material should yield evidence of the paleoecology and paleobiology of this sedimentary sequence.

5) Stromatolites from the Bulawayan Group. --- Morphological, organic geochemical and carbon isotopic studies are being carried out (with K.K. Kvenvolden, R.J. Horodyski, and D.Z. Oehler) on the oldest algal stromatolites now known, from the Early Precambrian ($>2.7 \times 10^9$ years old) Bulawayan Group of Rhodesia.

6) Microorganisms of the Bitter Springs Formation. --- Mrs. Jan Blacic (graduate student) is investigating the microflora of the Late Precambrian Bitter Springs Formation of central Australia, in an effort to detect new microorganisms, and to determine the distribution and paleoecology of various members of the biota.

7) Modern and Ordovician Blue-Green Algae. --- To investigate the occurrence of evolutionary conservatism in primitive procaryotic microorganisms, Mr. John Oehler (graduate student) is carrying out a comparative morphological and biochemical study of cellularly preserved Ordovician algae and their modern morphological counterparts (viz. Schizothrix and Lyngbya). Mr. Oehler has succeeded in artificially silicifying ("fossilizing") modern algae to serve as comparative material in this optical and electron microscopic study.

8) Primitive Vascular Plants. --- Scanning electron microscopic studies of the vascular strands in primitive vascular plants of the Rhynie chert flora of Scotland, and a comparison of these elements with those present in living primitive plants (e.g. Psilotum), are to be carried out by Miss Donna Fields (undergraduate study project). This study may give some indication of the nature of the transition from thallophytic organisms to the earliest higher plants.

DEGREES AWARDED TO STUDENTS RECEIVING SUPPORT FROM THE NASA NGL 05-007-003 GRANT DURING THE LAST SIX MONTHS

Ph.D. Degree	Dept.	Thesis Title	Advisor
Barry, D.	P.S.S.	Stimulated Resonances in The Plasma Ionosphonic Plasma	Coleman
Fong, M.Y.	Chem.	Raman Spectra of Calcite I, II, and III At High Pressures.	Nicol
Newman, G.E.	Engr.	Numerical Integration Techniques and Orbit Determination Applied to Jupiter's Ninth and Twelfth Satellites.	Herrick
Richard, G.	Engr.	Application of An Electro-Optical System to Autoradiography.	Mackey
Tiffany, P.	Engr.	A Solution For The Mass of Mercury Based On Analysis Of The Orbit of Icarus With Considerations To The Bulge Of The Sun And Possible Verification With Work Yet To Be Done On Geographos.	
Wang, S.	Engr.	Inelastic Buckling Of Thin Spherical Shells Under Point Loads At The Apex	Roberts
Master's Degree			
Alvi, Z.	Engr.	Predective Aspects of Monitored Medical Data	Di Stefano/ Stear
Johnson, G.	Engr.	Numerical Solution to The Multi-Component Conversation Equation Using Bifurcative Approximation.	Helbing
Reichert, R.	Engr.	Favorable-Elongation Ephemeris of Icarus	Herrick
Tsay, S.	Chem.	Study of Intermolecular Association: Solvent Effects of the Dimerization of Benzoic Acid	Hazi

Publications

Hazi, A.U.
The Stabilization Method of Calculating Resonance Energies: A Model Problem.

Herrick, S.
A Universal, Singularity-free Determination of an Orbit for Two Positions and Time Interval.

Kennedy, G.C.
The Genesis of Diamond Deposits.
Kyanite Eclogites.
Melting Curves of Lithium, Sodium, Potassium, and Pubidium to 80 Kilobars.

Libby, W.F.
Ice Sheets on Venus.
Ice Caps on Venus?
Fifth Source of Jupiter Decametric Radiation.
Day-Night Variation of Alouette II Secondary Resonances.
Eiskappen auf der Venus?
Collecting a Sample of Solar Wind: An Experimental Study of Its Capture in Metal Films.

Mackey, R.
Electro-Optic Deflection.

Riegel, K.
Observation of an Unusual Cold Cloud in the Galaxy.

Schopf, j.
Microorganisms from the Late Precambrian of South Australia.
Possible Algal Microfossils from the Late Pre-Cambrian of California.
Preliminary Examination of Lunar Samples from Apollo 11.